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Maintenance of the Highway Infrastructure

Structure Inspection and Evaluation System

Presented by
The Ministry of Transportation and Communications
Ontario, Canada

89-03135/

ONT-86-10

Maintenance of the Highway Infrastructure

Structure Inspection and Evaluation System

R.S. Reel
D.F. Conte

Published by:
Ontario Ministry of Transportation and Communications
Hon. Ed Fulton, Minister
D.G. Hobbs, Deputy Minister

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Transportation Industry Office
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8
(416) 248-7193

March 1986

ABSTRACT

Structure inspection and evaluation systems are required to ensure, within an economic framework, a uniform and acceptable standard for the condition of structures in terms of public safety, comfort, and convenience. This paper describes the inspection and evaluation practices in the province of Ontario.

A numeric condition rating system is used to assess the degree of severity of the material defects, based on the amount of structure component affected. A separate numeric condition rating system is used to assess defects in the performance of structure components.

Guidelines are presented for rating the observed material and performance defects for components of the structure. Examples of material and performance defects are illustrated.

Examples of inspection forms are given and the data from them will be entered into the Ontario Structure Inventory System (OSIS), currently under revision.

Guidelines are given for using the inspection data to establish and rate structure maintenance needs in order of priority and to develop annual and multi-year repair and rehabilitation programs for structures.

Evaluations for load-carrying capacity are carried out according to the provisions of the Ontario Highway Bridge Design Code when inspections indicate that the load-carrying capacity may be affected.

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1/ INTRODUCTION

The need for mobility requires that the highway system be kept in good repair. Structures are a vital part of the system, and the efficiency of the system is impaired and the public inconvenienced if a structure fails or its load capacity is reduced.

Routine inspection of structures in Ontario has been an established practice, with regular inspections at various levels. However, in the past, the inspectors relied on their own background and experience in reporting structural conditions. This practice often lead to disparity and different standards being used.

The Ontario Structure Inspection Manual (OSIM) [1] provides a uniform and rational approach for inspecting and recording the condition of structures and their components.

If the inspection indicates that the load capacity of a structure may be affected because of severe defects in the material or performance of the structure, then an evaluation for load-carrying capacity is conducted according to the provisions of the Ontario Highway Bridge Design Code (OHBDC) [2].

1.1/ Goals and Objectives

The goal of structural inspections and evaluations is to ensure, within an economic framework, an acceptable standard of structure condition in terms of public safety, comfort, and convenience.

The objectives of structural inspections and evaluations are to protect and prolong the useful life of structures, to identify repair and rehabilitation needs, and to provide a basis for a structure maintenance management system for planning and funding of the maintenance.

2/ LEVELS OF INSPECTIONS

The Ministry of Transportation and Communications (MTC) conducts the following routine and non-routine inspections on a regular basis:

2.1/ General Visual Inspections by District Patrol Supervisors

Daily routine inspection - while travelling in the patrol vehicle.

Monthly routine inspection - of structures.

Non-routine inspection - after vehicular collision with a structure, spring run-off, prolonged extreme temperatures, or other circumstances at the discretion of the District Maintenance Engineer.

2.2/ General Visual Inspections by District Bridge Foremen

Annual routine inspection - where a problem has been identified, in detail.

Biennial routine inspection - of structures.

Non-routine inspection - of a structure with an identified problem.

2.3/ Detailed Inspections by Regional Structural Sections

Biennial routine inspection - detailed visual inspection of structures according to OSIM.

Non-routine inspection
- detailed visual inspection of a structure with an identified problem.
- detailed deck condition surveys according to the Deck Rehabilitation Manual.
- at the request of a municipality.

2.4/ Principal Inspections by Regional Structural Sections

Principal inspections require the measurement and documentation of all areas of defects and deterioration on a structure and, therefore, require access to all parts of the structure, which may be provided by ladders, scaffolding, mobile platforms, and buckets. Figures 1 and 2 show

principal inspections being performed using mobile equipment.

Principal inspections of structures are conducted on the following basis:

Non-routine inspection	- before repair or rehabilitation of the structure. - where a problem has been identified.
Routine inspection	- in future, on selected structures, every five years .

2.5/ Inspections by Structural Office

Non-routine inspections	- detailed inspections upon request. - detailed inspections for approval of load-limit bylaws. - condition surveys for load-carrying capacity. - principal inspections upon request.

2.6/ Emergency Inspections

Emergency inspections procedures are carried out when a component contributing to the overall strength or stability of the structure is in imminent danger of failure or has failed because of material or performance defects or vehicular collision.

2.7/ Application of OSIM Procedures

The inspection procedures as detailed in OSIM apply to the routine detailed inspections by Regional Structural Sections and may also be applied for routine general inspections by district bridge foremen. The general principles of OSIM may also be applied to routine general inspections by district patrol supervisors.

The inspection procedures in OSIM do not apply to the mechanical or electrical components of movable structures.

3/ CONDITION RATING SYSTEMS IN OSIM

Separate condition rating systems are used to assess the material and performance conditions of individual components of a structure and the performance condition of the structure as a whole.

The rating of the performance defect is not necessarily the same as that of the material defect; therefore, the same component may have different material and performance condition ratings.

The individual components of a structure are identified as either primary, secondary, or auxiliary, depending on the degree to which they contribute to structure strength and stability.

3.1/ Material Condition Rating System (MCR)

The material condition rating system for the components of a structure is a numerical system in which a number between 1 and 6 is assigned to each component, which best represents the condition of the component, based on observed defects in its material.

Typical defects in the materials commonly used in structures are described and categorized as to severity in Part 1 of OSIM and will not be addressed in this paper.

The application of the material condition rating system to components depends on the type, location, and severity of the observed material defect. Guidelines for its application are generalized for a number of defects and are given in Figure 3 for primary, secondary, and auxiliary components. Exceptions to the guidelines given there and additional guidelines specific to a particular component are given in the individual component sections of OSIM.

The material condition rating should represent the worst observed material condition and shall be based upon any one or combination of the guidelines given under that rating. Where possible, the inspector should also attempt to identify the cause producing the defect. Some measurements may be required to determine and describe the location and extent

of the defect; however, extensive measurements would not normally be required.

3.2/ Performance Condition Rating System (PCR)

The performance condition rating system for the components of a structure is a numerical system in which a number between 1 and 6 is assigned to each component, which best represents the condition of the component, based on its ability to perform its intended function in the structure.

Performance defects are often closely related to, or are as a result of, material defects. Performance defects may also result from errors in design or construction, unexpected behaviour of the structure, or defects in other components of the structure.

The application of the performance condition rating system to components depends on the type of component and on the location and severity of the observed defect. General guidelines based on the percentage reduction in the capacity of the component to perform its intended function are given in Figure 4. Additional guidelines which are related to the specific function of each component in the structure are given in the individual component sections of OSIM.

3.3/ Performance Condition Rating of the Structure (PCRS)

The lowest performance condition rating of a primary component shall also be the performance condition rating for the structure as a whole. Ratings of different primary components are not combined to arrive at the rating for the structure.

4/ APPLICATION OF THE CONDITION RATING SYSTEM

Guidelines on the application of the material and performance condition rating systems are given in Part 2 of OSIM for each component of the structure. In this paper, only the guidelines as they apply to the deck components are given.

4.1/ Deck Components

Deck components considered herein are thin slab decks, the top surfaces of voided slab or thick solid slab decks, wearing surfaces, curbs, sidewalks, medians, barrier walls, railings, and deck drainage systems.

Decks and wearing surfaces are considered primary components; curbs, sidewalks, medians, barrier walls, and railings are secondary components; and deck drainage systems are auxiliary components.

Prior to detailed inspection of the deck and deck components, the inspector shall note if general maintenance has been performed by the district in accordance with maintenance quality standards.

4.1.1/ Material Condition Rating of Deck Components

The inspector shall record the extent and location of observed material defects of the deck components and shall inspect the following with particular care:

- cracking, delaminations, and spalling of concrete;
- scaling and disintegration of concrete;
- insufficient concrete cover to reinforcing steel, as evident from exposed reinforcing in spalled areas and by rust stains on exposed concrete deck surfaces;
- corrosion of imbedded reinforcing steel, as evident from rust stains on concrete surfaces;
- the deterioration of the soffit and stay-in-place forms;
- deterioration and breakup of the joint between the deck and abutment and between the abutment and approach slab;
- cracking, ravelling, potholes, and breakup of asphalt wearing surfaces;
- loss of bond and separation of the wearing surface;
- deterioration of waterproofing materials;
- wheel track rutting, rippling, and flushing of asphalt wearing surfaces;
- deterioration and breakup of curbs and sidewalks at expansion joints;
- erosion of material from under approach slabs;

- deck drainpipes not properly anchored to structure or connections not adequately secured;
- broken drainpipes or connections.

Guidelines to assist the inspector in the condition rating of observed material defects in deck components are given in Figure 5.

4.1.2/ Performance Condition Rating of Deck Components

The inspector shall record the extent and location of observed performance defects of decks and wearing surfaces and shall inspect the following with particular care:

- loss of section strength or capacity due to defects in component material;
- loss of protection to underlying surfaces due to defects in the wearing surface materials;
- loss in riding comfort and potential loss of vehicle control due to defects in the component material;
- overloading, either a single or repetitive occurrence, resulting in permanent deformations of the deck or deck components;
- horizontal, vertical, or rotational displacements in curbs or sidewalks;
- water ponding or ice on sidewalks;
- inadequate curb height;
- inadequate provision for drainage off the deck or approaches, with insufficient number of drains or inadequate drain sizes;
- inadequate slopes or sharp directional changes in deck drains or drainage systems;
- drainage system partially or completely plugged;
- drainage outlets discharging onto other structure components, embankments, or roadways below.

Guidelines to assist the inspector in the condition rating of observed performance defects in primary deck components are given in Figure 6.

4.1.3/ Examples

Typical examples of material and performance defects in deck components and the condition rating which would be applied to them are illustrated in Figures 7 and 8.

5/ INSPECTION FORMS

Examples of forms for general structure information, inspection of the deck components of a structure, and summary recommendations are given in Figures 9, 10, and 11, respectively.

6/ PROGRAMMING OF DETAILED INVESTIGATIONS, REPAIRS, AND REHABILITATION

The condition ratings provide a framework for decisions on additional work or investigations that may be required and suggest a timetable for this work. For example, the need for, and programming of, detailed deck condition surveys is based on the material condition rating of the deck and guidelines for concrete decks, as given in Figure 12. The equipment typically used for performing detailed deck surveys is shown in Figure 13.

The overall performance condition rating of the structure is used to identify the need to perform an evaluation for load-carrying capacity and/or to post the structure for live load. Suggested guidelines for posting and evaluation are given in Figure 14. A structure that has been recently damaged and requires immediate posting is shown in Figure 15.

The condition ratings of individual structure components are used to identify needed repairs or rehabilitation and to plan the time schedule for this work, as shown in Figure 16.

7/ EVALUATION FOR LOAD-CARRYING CAPACITY

7.1/ Need for Evaluation

Evaluations for load-carrying capacity are conducted (using Section 14 of the OHBDC) for the following reasons:

- material or performance defects or damage;
- changes in load specifications, road classification, or load restriction;
- rehabilitation;
- a controlled vehicle to use the bridge.

7.2/ Condition Survey

A condition survey of the bridge to be evaluated is carried out to the satisfaction of the engineer in charge of the evaluation. All relevant measurements are recorded and material and performance defects noted and compared with existing data on the structure.

Guidelines for conducting condition surveys and on the strength properties of the materials are given in Section 14 of the OHBDC.

7.3/ Evaluation Procedures

7.3.1/ General

Evaluations are carried out for dead loads, Ontario highway bridge evaluation loads (Figure 17), and for controlled vehicle loads. Evaluations for other transitory loads are also considered if requested by the engineer.

7.3.2/ Limit States

Ultimate limit states are used in the evaluation. Serviceability limit states are used only if deemed to be of consequence by the engineer.

7.3.3/ Loading Combinations and Factored Loads

Evaluations are conducted for factored permanent loads plus factored live loads. Dead load factors are different for different materials.

Load factors for dead loads may be reduced if sufficient data are collected during the condition survey to justify a reduction. The load factor for live loads may be reduced from 1.4 to 1.25 if the bridge is to

be re-evaluated within five years. The load factor for controlled vehicles may be as low as 1.15, and dynamic load allowance may be reduced if restrictions on speed are enforced.

7.3.4/ Performance Factors

Performance factors are specified in the relevant sections of the OHBDC.

7.3.5/ Effects of Deteriorations

The reduction in factored resistance due to material defects is considered. Where deterioration in a component is extensive and affects the load distribution of the structure, the following are also considered:

- increase in load effects in adjacent components, and
- decrease in load effects in the deteriorated component.

7.3.6/ Factored Resistance

Factored resistance for reinforced concrete, prestressed concrete, structural steel, wood, and substructure components is calculated in accordance with the appropriate section of the OHBDC.

Rational methods of calculating factored resistance are acceptable for components not covered in Section 14 or in other sections of the OHBDC.

7.4/ Bridge Posting

Calculations according to Section 14 lead to a triple load posting for bridges. In certain cases a single posting based on engineering judgement and experience may be used.

A concrete bridge which has been carrying normal traffic without signs of distress is not posted.

7.4.1/ Scale-Down Factor, "F"

For all structure components of the bridge, except for deck slabs, the smallest value of "F" is calculated for evaluation levels 1, 2, and 3 and for controlled vehicles from the following equation:

$$F = \frac{\phi\ Rn - \text{load effects due to factored dead loads}}{\text{load effects due to factored live loads}}$$

where ϕ is the appropriate performance factor
Rn is the ultimate resistance of the component

For concrete deck slabs, the smallest value of F is calculated for wheel loads of evaluation levels 1, 2, and 3 and controlled vehicles from the following equation:

$$F = \frac{\phi\ Rn}{Lo}$$

where ϕ is equal to 0.5
Rn is obtained from graphs in Figure 18
Lo is the factored wheel load, including dynamic allowance

7.5/ Calculation of Posting Loads

The posting loads are obtained as follows:

Level 3
If F > 1.0, then posting is not required.

Level 2 and 3
If F > 0.3, then triple posting is required and obtained from Figures 19, 20, and 21 for levels 1, 2, and 3, respectively.

Level 1
If F < 0.3, then the bridge may be closed.

7.6/ Calculations for Controlled Vehicles

If F > 1.0, then the bridge is considered safe for the vehicle.

7.7/ Posting Signs

A single and a triple posting sign are shown in Figure 22. A posted structure which is structurally deficient is shown in Figure 23.

7.8/ Load Testing

Bridges are considered for load testing if analytical evaluations are unsatisfactory.

8/ WORK FLOW DIAGRAM

Figure 24 shows the flow of work as it applies to recording data in the structure inventory system and to conducting inspections, condition surveys, posting, and load testing.

9/ REFERENCES

[1] Ontario Structure Inspection Manual, Ontario Ministry of Transportation and Communications, Downsview, 1985.

[2] Ontario Highway Bridge Design Code, Ontario Ministry of Transportation and Communications, Downsview, 1983.

Figure 1/ Non-Routine Principal Inspection Using Inspector 50

Figure 2/ Non-Routine Principal Inspection Using Bucket

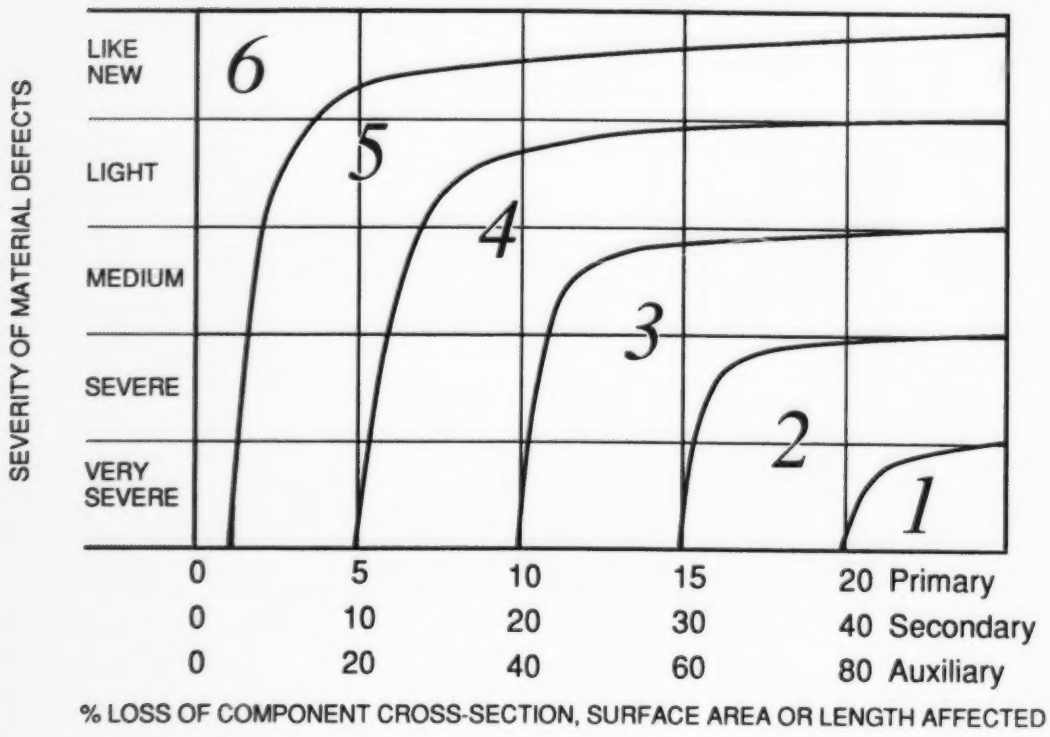

Figure 3/ Material Condition Rating of Structure Components

RATING	PERFORMANCE CONDITION OF COMPONENT	APPROXIMATE PERCENTAGE REDUCTION IN THE CAPACITY OF THE COMPONENT TO PERFORM ITS INTENDED FUNCTION IN THE STRUCTURE		
		PRIMARY COMPONENTS	SECONDARY COMPONENTS	AUXILIARY COMPONENTS
9	COMPONENT CANNOT BE INSPECTED	NA	NA	NA
6	VERY GOOD	0	0	0
5	GOOD	0 TO 5%	0 TO 10%	0 TO 20%
4	FAIR	5 TO 10%	10 TO 20%	20 TO 40%
3	POOR	10 TO 15%	20 TO 30%	40 TO 60%
2	URGENT	15 TO 20%	30 TO 40%	60 TO 80%
1	CRITICAL	OVER 20%	OVER 40%	OVER 80%
0	COMPONENT NON-EXISTENT	NA	NA	NA

Figure 4/ Performance Condition Rating of Structure Components

Rating	Observed Material Defects
6	-No material defects in the deck or wearing surface.
5	- Many locations of light defects over up to 10% of the wearing surface. - Defects over up to 5% of the surface of exposed concrete decks. - Surface defects over up to 5% of the deck soffit.
4	- Many locations of medium defects over 10% to 20% of the wearing surface. - Defects over 5% to 10% of the surface of exposed concrete decks. - Surface defects over 5% to 10% of the deck soffit.
3	- Many locations of severe defects over 20% to 30% of the wearing surface. - Defects over 10% to 15% of the surface of exposed concrete decks. - Surface defects over 10% to 15% of the deck soffit.
2	- Many locations of very severe defects over 30% to 40% of the wearing surface. - Defects over 15% to 20% of the surface of exposed concrete decks. - Surface defects over 15% to 20% of the deck soffit.
1	- Many locations of very severe defects over more than 40% of the wearing surface. - Areas of the deck have punched through. - Defects over more than 20% of the surface of exposed concrete decks. - Surface defects over more than 20% of the deck soffit.

Figure 5/ Guidelines for the Material Condition Rating of Primary Deck Components

Rating	Observed Performance Defects
6	- No performance defects. - Deck or wearing surface is uniform and provides a smooth and comfortable ride.
5	- Deck is satisfactorily carrying and transferring load to supporting superstructure components. - Deck or wearing surface is slightly rough and provides a slightly rough ride.
4	- Deck is adequately carrying and transferring load to supporting superstructure components. - Deck or wearing surface is uneven and provides a rough ride but no difficulty in maintaining vehicle control.
3	- Some parts of the deck are not capable of supporting heavy truck wheel loads. - Deck or wearing surface is uneven producing a rough ride with slight difficulty in maintaining vehicle control. - A slightly slippery deck or wearing surface.
2	- Some parts of the deck are not capable of supporting light truck wheel loads. - Deck or wearing surface is irregular producing a rough ride with moderate difficulty in maintaining vehicle control. - A moderately slippery deck or wearing surface.
1	- Some parts of the deck have failed. - Some parts of the deck are not capable of supporting car wheel loads. - Deck or wearing surface is irregular producing a very rough ride with extreme difficulty in maintaining vehicle control. - A very slippery deck or wearing surface.

Figure 6/ Guidelines for the Performance Condition Rating of Primary Deck Components

Figure 7/ Condition Ratings of a Concrete Deck Top Surface
MCR = 3 – Previously repaired delaminated areas; over 15% of the surface is delaminating again.
PCR = 5 – Deck provides a slightly rough ride.

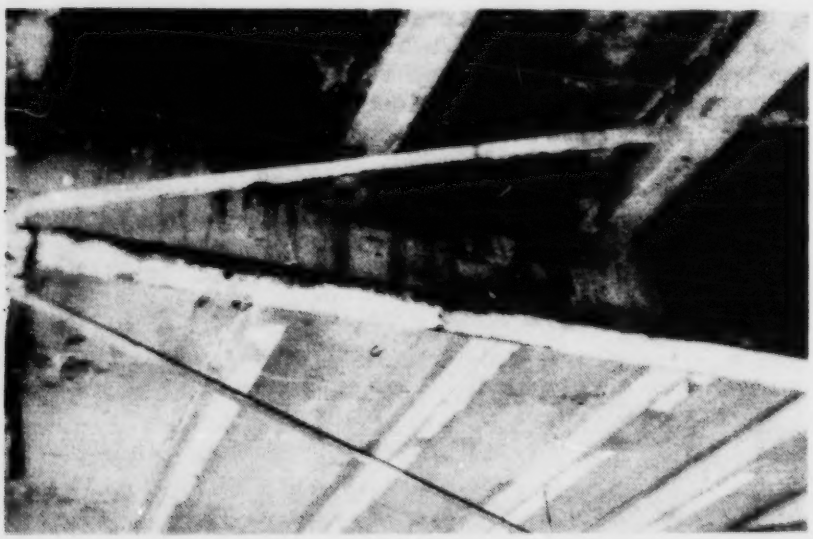

Figure 8/ Condition Ratings of a Concrete Deck Soffit
MCR = 3 – Numerous locations of surface deposits and staining, with delaminations and spalling of concrete over the top flanges of the floor beams and stringers.
PCR = 4 – Deck is adequately carrying and distributing load.

ONTARIO STRUCTURE INSPECTION MANUAL

GENERAL INFORMATION

STRUCTURE NAME _____ COUNTY SITE NUMBER _____
HIGHWAY NUMBER ABOVE _____ BELOW _____ DIST._____
NUMBER OF SPANS _____ SPAN LENGTH _____
ROADWAY WIDTH _____ DATE OF CONSTRUCTION _____

SEQUENCE NUMBER _____ TOWNSHIP NUMBER _____
LHRS NUMBER _____ BRIDGE NUMBER (MUNIC.)_____
LOCATION _____ JURISDICTION _____

INSPECTOR'S NAME _____ DATE _____
DIRECTION OF INSPECTION _____ TEMP _____
EQUIPMENT USED _____

RATING SYSTEM
6 - VERY GOOD
5 - GOOD
4 - FAIR
3 - POOR
2 - URGENT
1 - CRITICAL
0 - COMPONENT DOES NOT EXIST
9 - COMPONENT CANNOT BE INSPECTED

ABBREVIATIONS
T - TYPE OF COMPONENT
P - PRIMARY COMPONENT
S - SECONDARY COMPONENT
A - AUXILIARY COMPONENT
MCR - MATERIAL CONDITION RATING
PCR - PERFORMANCE CONDITION RATING
PC - CONDITION RATING OF COATING
PCRS - PERFORMANCE CONDITION RATING OF STRUCTURE

Figure 9/ General Information on Structure

DECK COMPONENTS SPAN _____ NUMBER OF SPANS _____

#	T	MCR	PCR	PC	COMPONENT	REMARKS
1	P				SOFFIT	
2	S				S I P FORMS	
3	P				DECK TOP SURFACE	
4	P				WEARING SURFACE	
5	S				WATERPROOFING	
6	S				___ END JOINT	
7	S				___ END DAM	
8	S				INTERIOR JOINTS	
9	S				INTERIOR DAMS	
10	S				___ END JOINT	
11	S				___ END DAM	
12	S				___ RAILING	
13	S				___ SIDEWALK/CURB	
14	S				___ CURB FACE	
15	A				___ DRAINAGE	
16	S				MEDIAN	
17	A				___ DRAINAGE	
18	S				___ CURB FACE	
19	S				___ SIDEWALK/CURB	
20	S				___ RAILING	

Figure 10/ Inspection Form for Deck Components

ONTARIO STRUCTURE INSPECTION MANUAL

PCRS - OVERALL PERFORMANCE CONDITION RATING OF THE STRUCTURE _____

CONTROLLING COMPONENT _____

RECOMMENDATIONS

ADDITIONAL INVESTIGATIONS REQUIRED

YES	NO	
____	____	DETAILED DECK CONDITION SURVEY
____	____	DETAILED COATING CONDITION SURVEY
____	____	STRUCTURE EVALUATION FOR LIVE LOAD
____	____	LOAD LIMIT POSTING - ESTIMATED LOAD _____ TONNES.

REPAIRS BY DISTRICT

REPAIRS BY CONTRACT

REHABILITATION DESIGN BY REGIONAL STRUCTURAL SECTION

Figure 11/ Inspection Summary and Repair/Rehabilitation Recommendations

MCR OF DECK	TIME PERIOD FOR DETAILED DECK CONDITION SURVEY
6	8 OR MORE YEARS
5	4 TO 8 YEARS
4	1 TO 3 YEARS
3	IMMEDIATELY
2	MAY NOT HAVE SUFFICIENT TIME
1	MAY NOT HAVE SUFFICIENT TIME

Figure 12/ Time Period for Detailed Deck Condition Surveys

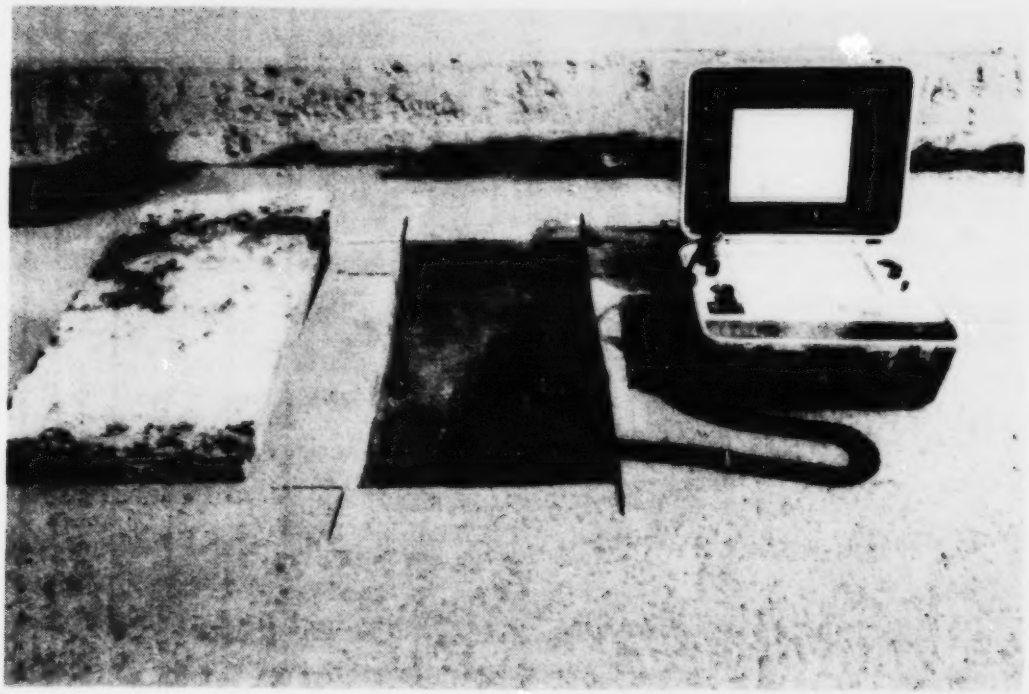

Figure 13/ Equipment Used for Detailed Deck Condition Surveys

PCR OF STRUCTURE	REQUIREMENTS FOR POSTING AND EVALUATION
6	-LOAD LIMIT POSTING NOT REQUIRED -EVALUATION NOT REQUIRED
5	-LOAD LIMIT POSTING NOT REQUIRED -EVALUATION NOT REQUIRED
4	-LOAD LIMIT POSTING NOT NORMALLY REQUIRED -EVALUATION SHOULD BE REQUESTED IF NECESSARY
3	-LOAD LIMIT POSTING MAY BE REQUIRED -EVALUATION SHOULD BE RECOMMENDED
2	-LOAD LIMIT POSTING REQUIRED IMMEDIATELY AND BASED UPON VISUAL INSPECTION -EVALUATION REQUIRED
1	-LOAD LIMIT POSTING REQUIRED IMMEDIATELY AND BASED UPON VISUAL INSPECTION. ALTERNATIVELY, THE STRUCTURE MAY HAVE TO BE CLOSED TO TRAFFIC. -EVALUATION REQUIRED

Figure 14/ Guidelines for Load Limit Posting and Structure Evaluations

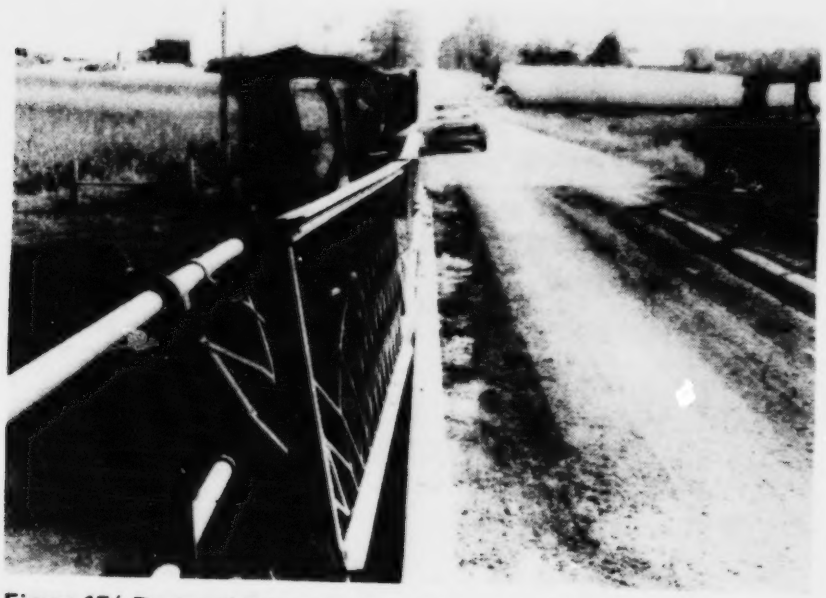

Figure 15/ Damaged Structure Requiring Immediate Posting

MCR OR PCR OF COMPONENT	TIME PERIOD FOR REPAIR
6	10 OR MORE YEARS
5	6 TO 10 YEARS
4	3 TO 5 YEARS
3	1 TO 2 YEARS
2	WITHIN 1 YEAR
1	IMMEDIATELY

Figure 16/ Time Period for Repair/Rehabilitation of Components

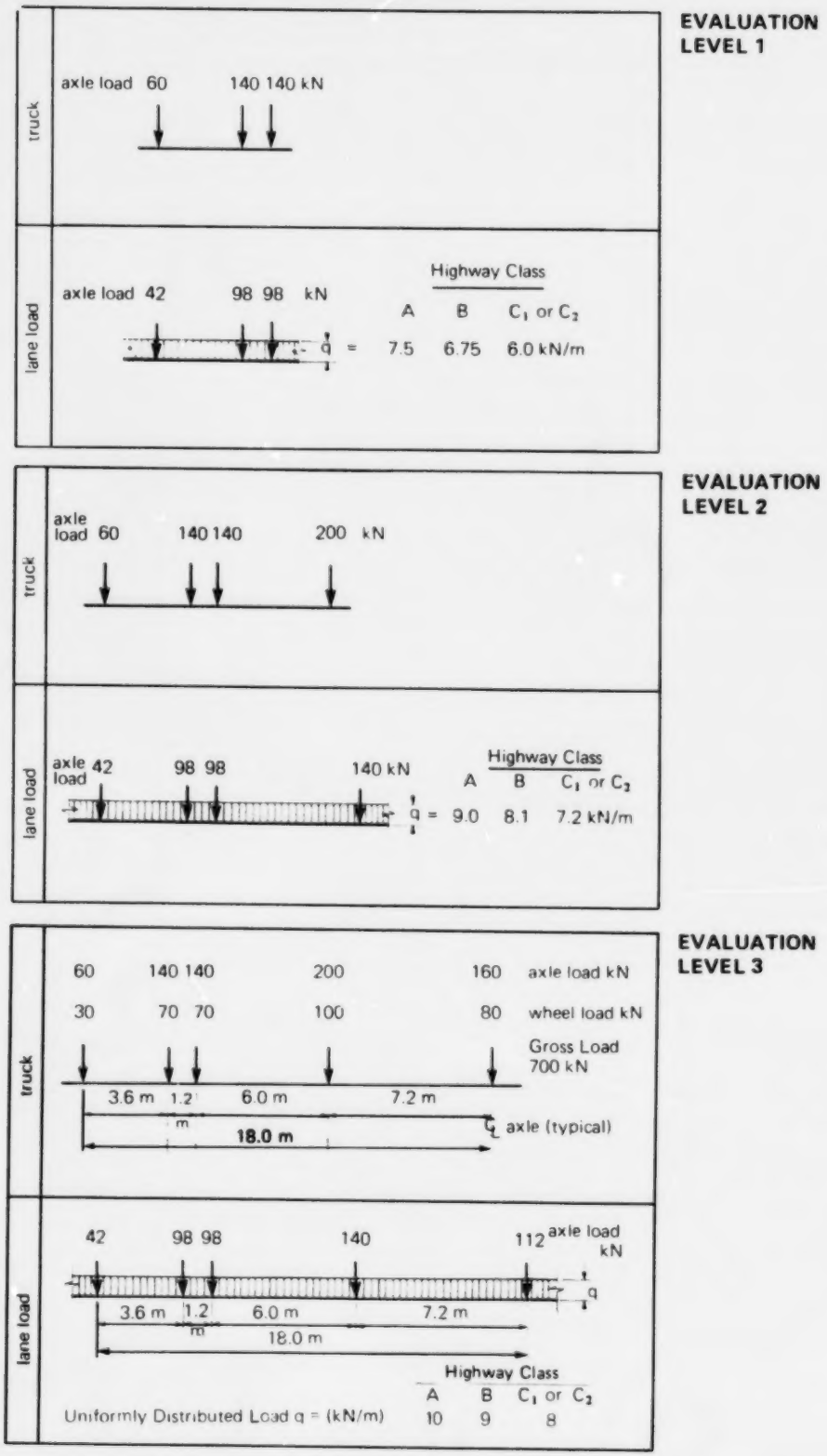

Figure 17/ Ontario Highway Bridge Evaluation Loads

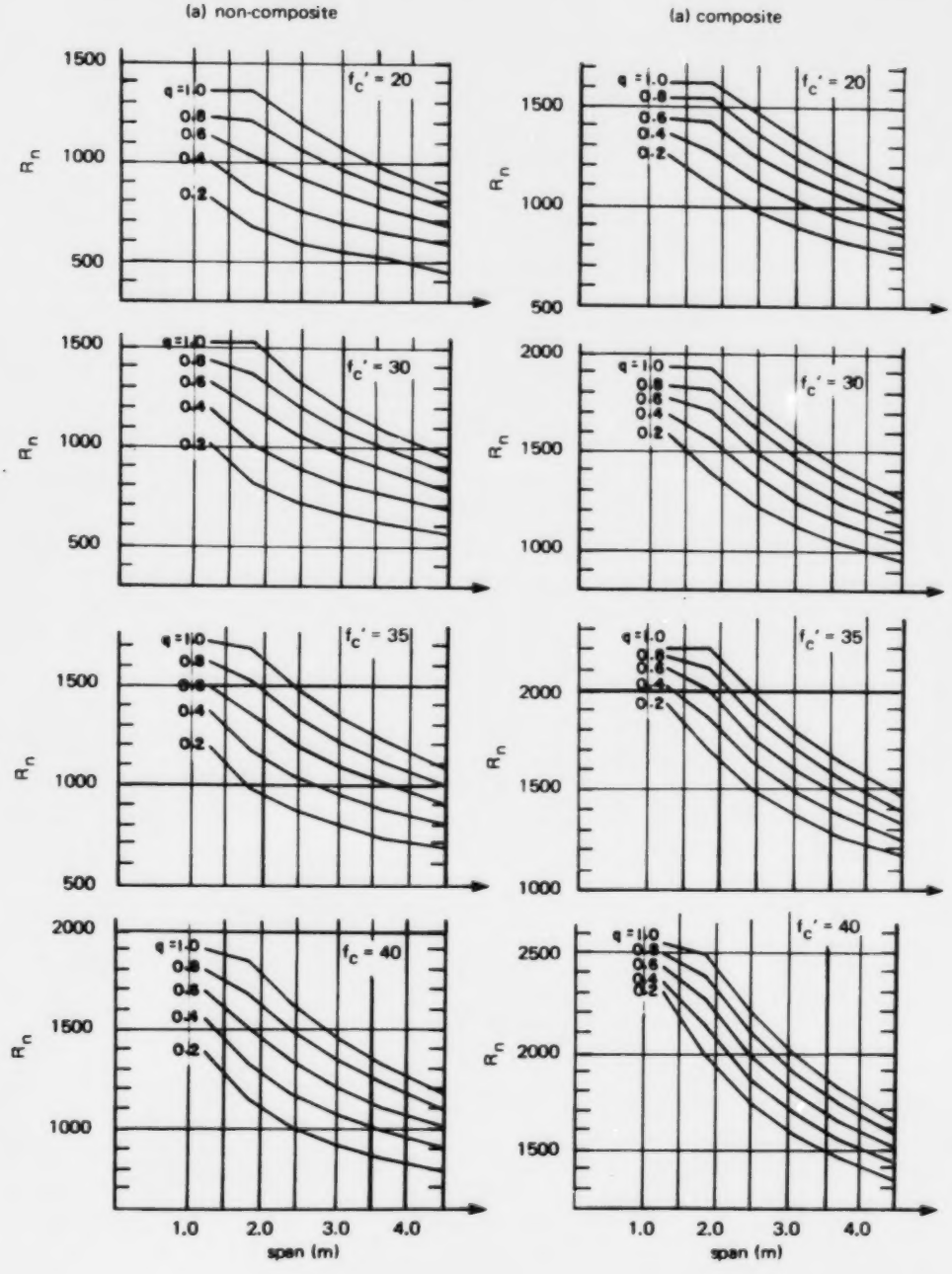

Figure 18/ Values of Rn for a 225 mm Concrete Deck

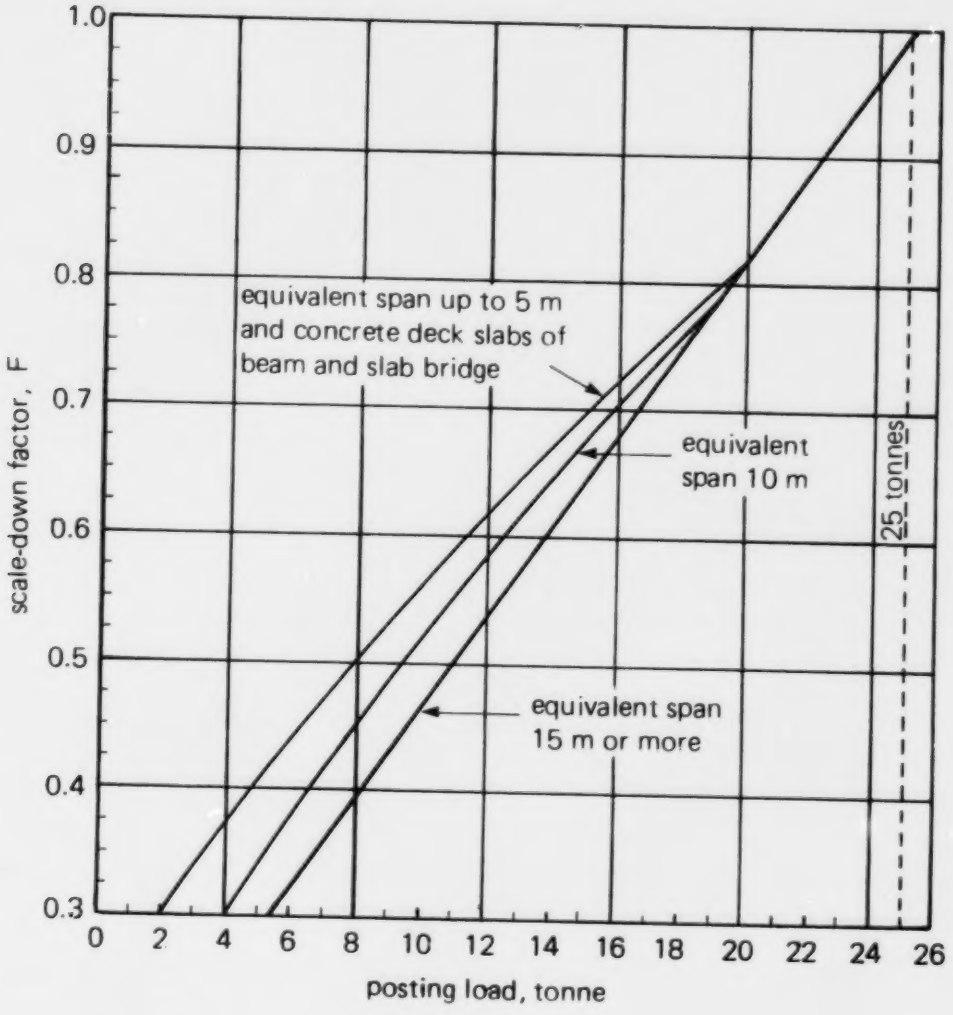

Figure 19/ Posting Loads Corresponding to Evaluation Level 1 Loads

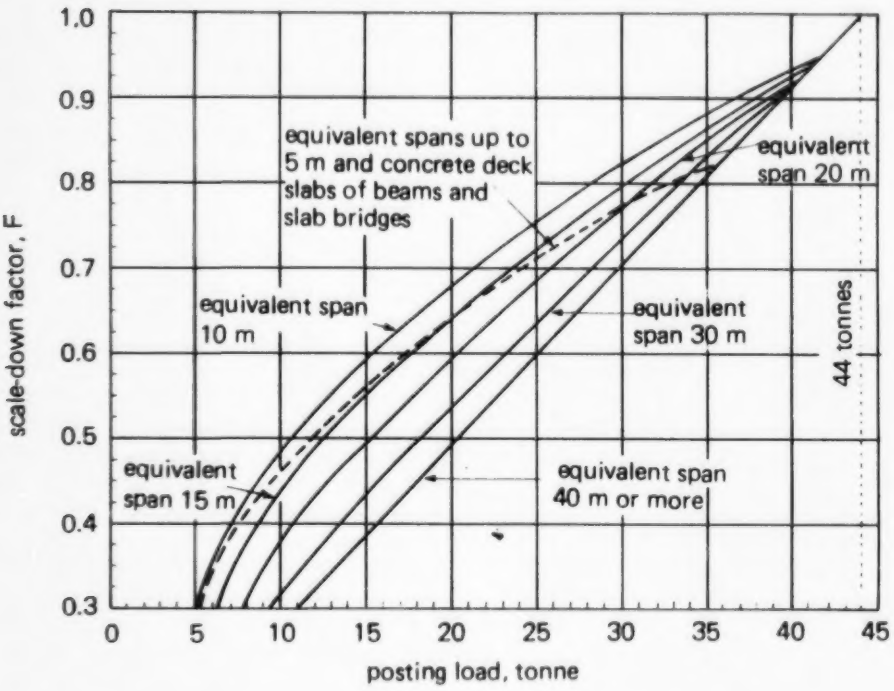

Figure 20/ Posting Loads Corresponding to Evaluation Level 2 Loads

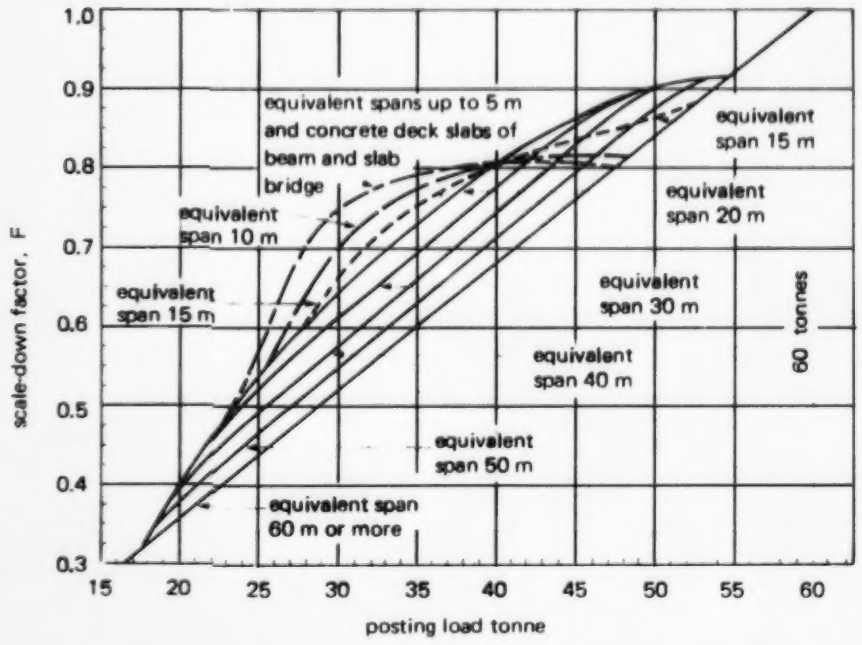

Figure 21/ Posting Loads Corresponding to Evaluation Level 3 Loads

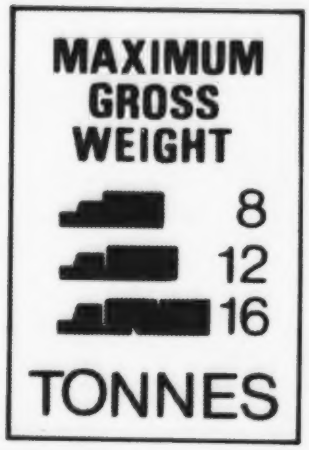

Figure 22/ Posting Signs

Figure 23/ Posted Bridge

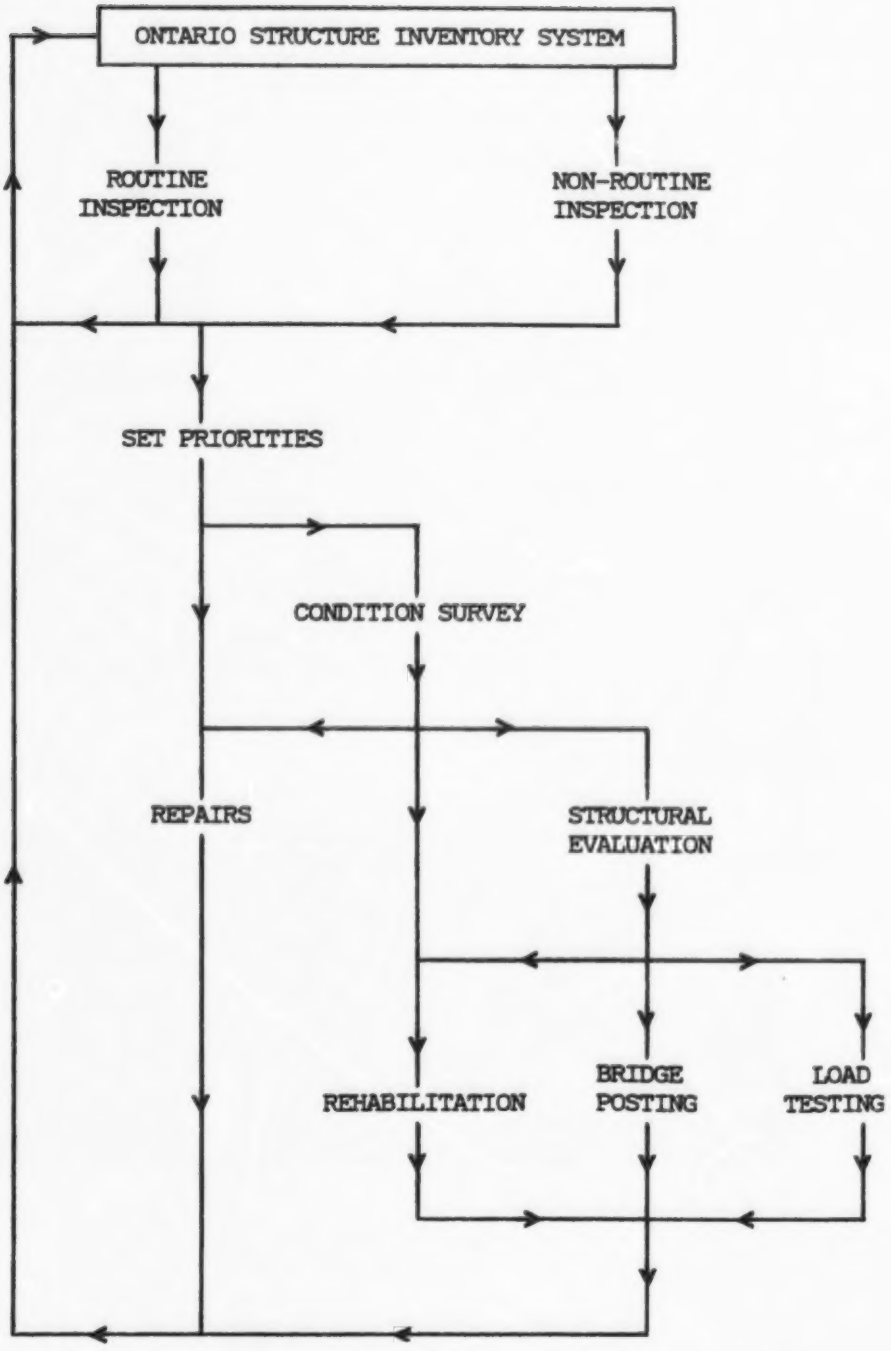

Figure 24/ Work Flow Diagram

Ontario

Ministry of
Transportation and
Communications
Hon. Ed Fulton
Minister